Poster submitted for presentation at OSA meeting
Optical Remote Sensing of the Atmosphere
Santa Fe, February 9 14, 1997

Dual wavelength Raman lidar observations of tropical cirrus clouds during the ALBATROSS campaign 1996

G. Beyerle[3] H.-J. Schäfer[2], R. Neuber[3], P. Rairoux[3], O. Schrems[2], I. S. McDermid[1]

[1] Jet Propulsion Laboratory, Table Mountain Facility, California Institute of Technology, Wrightwood, CA 92397-0367, USA, Tel.: (619) 249-6176, Fax: (619) 249-5392
[2] Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[3] Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany

introduction

Recent model calculations have shown that the extreme dry ness of the tropical lower stratosphere can be explained by slow uplift of air masses by large-scale motions leading to the formation of an ubiquitious cirrus cloud layer [1]. We present first results from lidar observations of tropical cirrus clouds above the Atlantic ocean during the ALBATROSS campaign (At mospheric chemistry and lidar studies above the Atlantic ocean related to ozone and other trace gases in the tropo- and stratosphere) in October- November 1996.

Instrumentation and data reduction

The measurements of high-altitude tropical cirrus were performed with a mobile aerosol Raman lidar aboard the German research vessel "POLARSTERN". The instrument transmits simultaneously at wavelengths of 355 and 532 nm. Elastic and inelastic components of the backscattered light (Rayleigh- and Mie-scattering, vibrational Raman-scattering on molecular nitrogen) are detected. Additionally, the cross-polarized signals at 355 and 532 nm are recorded. Currently the instrument operates during night-time only. Further technical details can be found in Schäfer et al.[2].
After applying background and saturation corrections to the raw signals the backscatter ratio $R = 1 + \beta_A/\beta_M$ is derived by dividing the Rayleigh and corresponding Raman profile and normalizing to unity at an aerosol-free altitude range between 18 and 22 km. Here, $\beta_{A,M}$ denote the aerosol and molecular backscatter coefficient, respectively. Similarly, volume depolarization $\delta = \beta^{\perp}/\beta^{\|}$ is calculated by forming the ratio of the signals in the cross- and aligned-polarization channels and normalizing to 0.014. The superscripts $\perp$, $\|$ refer to cross- and aligned- polarization, respectively.

Results and discussion

During the campaign lidar measurements were performed on the Atlantic ocean between 35°N and 45°S. In the following we restrict the discussion to the tropical and subtropical observations (30 °N-30°S). Based on one hour averages a total of 126 lidar profiles were obtained within this latitude range.
The measurements show that volume depolarization δ is an extremly sensitive parameter for the detection of subvisible cirrus clouds as non-spherical cirrus ice particles cause depolarizations reaching up to 100% (cf. figure 2) whereas for molecular scattering $\delta = 1.4\%$. In the tropics (23.5°S 23.5°N)

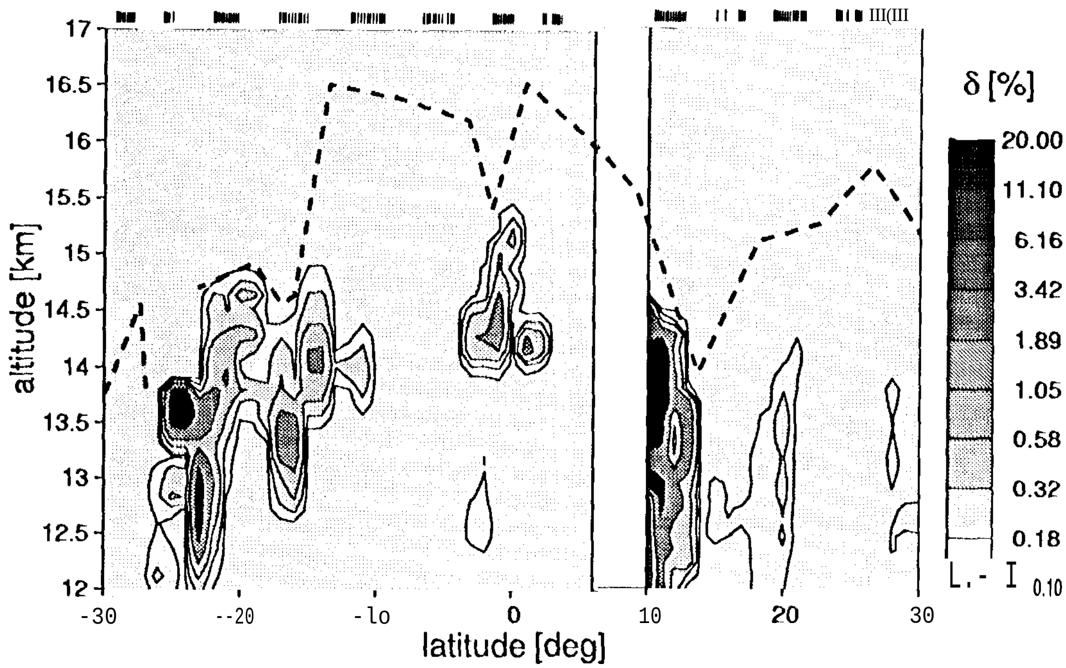

Figure 1: The altitude dependence of volume depolarization at a wavelength of 532 nm as a function of latitude. Also given is the tropopause altitude (broken line). Bars above the figure show the measurement periods.

we find in 44% out of 90 profiles maximum volume depolarizations exceeding 10% within the altitude range 12-16 km. In the subtropics (23.5 30°S and 23.5 30°N) this percentage reduces to 11 % based on 36 profiles.

In figure 1 the altitude dependence of δ as a function of latitude at 532 nm is given. Also shown is the tropopause altitude obtained from daily serological soundings. Frequently several distinct layers were found within the cirrus cloud with the highest layers reaching the tropopause. We found no indication for the presence of cirrus clouds in the lower stratosphere.

The frequent occurrence of highly depolarizing cloud layers with modest vaues of R is illustrated in figure 2. For 21% of the observations with $R_{532nm} < 1.5$ we find enhanced aerosol depolarizations with δ_A exceeding 10%.

Based on the ratio of aerosol backscatter coefficients at 532 and 355 nm an estimate of the particle sizes were derived within the framework of Mie scattering theory. As Mie theory is valid for spherical particles only measurements with $\delta_A < 0.1$ were included. The resulting ice water content (IWC) as a function of temperature T is shown in figure 3. The full line shows the result of linear fit, $IWC = \exp(-32.35 + 0.114\ \mathrm{K}^{-1} \cdot T)\ \mathrm{g/m^3}$. The broken line is a parametrization from Suzuki et al. [3].

References

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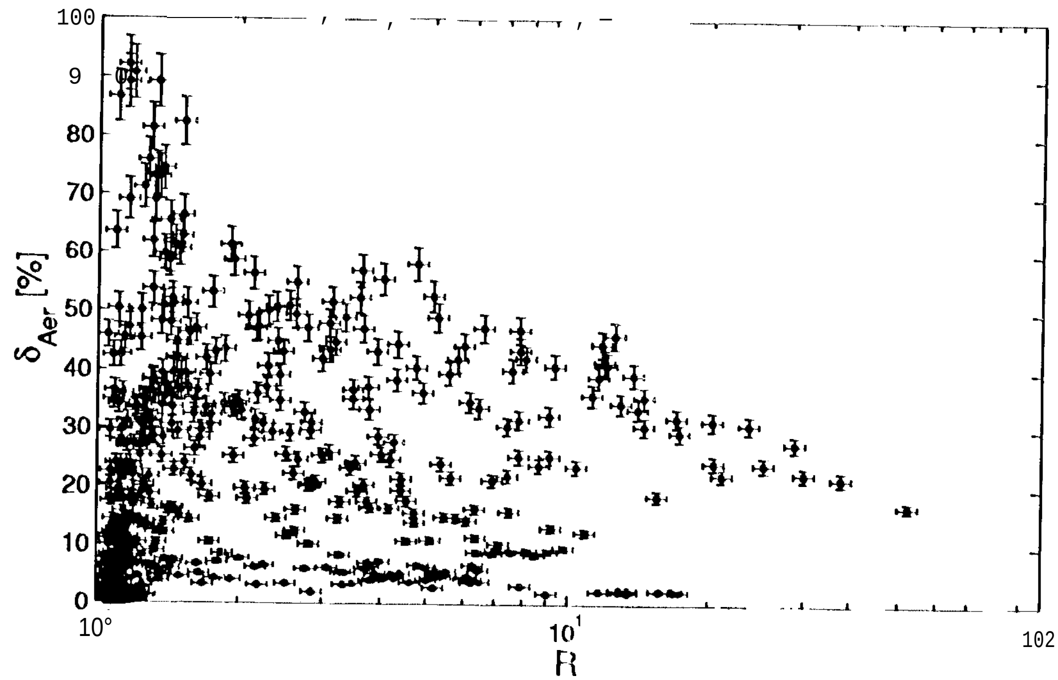

Figure 2: Aerosol depolarization as a function of backscatter ratio at 532 nm in the altitude range 12-16 km.

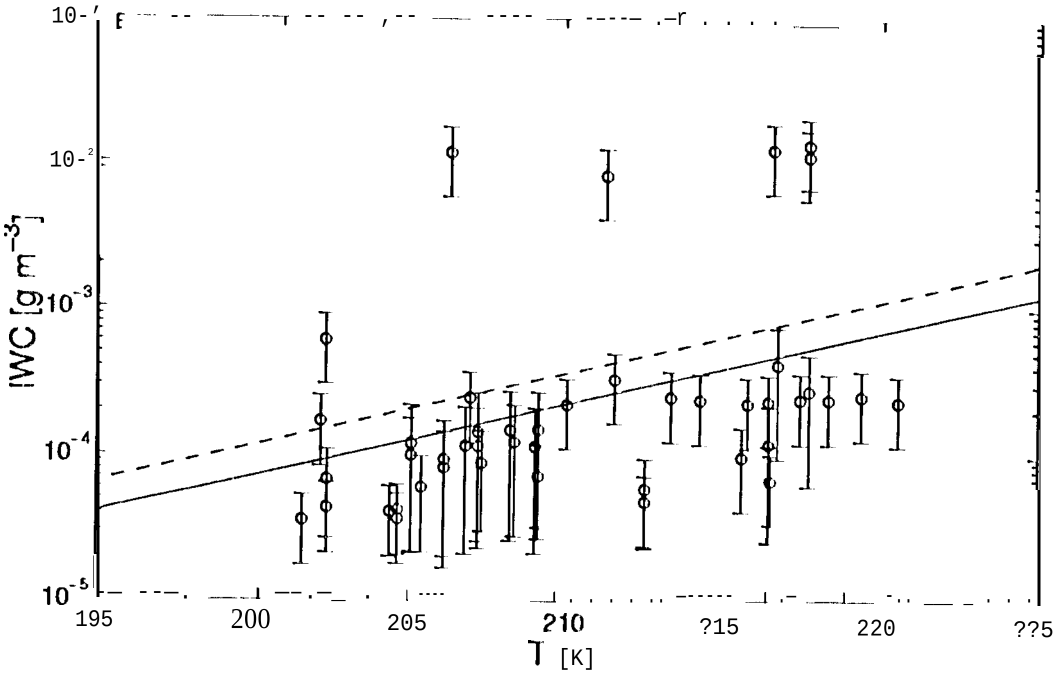

Figure 3: Ice water content (IWC) as a function of temperature. Also shown are a linear fit through the data (full line) and a parametrization by Suzuki et, al. (broken line).